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Full Length Research

Soil factors Influencing the Availability of Manganese in Soils of Agricultural Land-use System in a Coastal Plain Sands of Umudike

Ernest U. Eteng

Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike, Nigeria.

Author's Email ✉: eteng_em@yahoo.com

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The research was conducted in 2017 at the Michael Okpara University Agriculture, Umudike to investigate soil factors influencing the availability of Mn in soils of agricultural land-use systems. Soil samples were collected from two depths (0-20 and 20-40 cm) from five selected land use types; cassava farm, legume fallow, rice farm, forest reserved and grazing fields using a soil auger. Available Mn in the soils was determined using four extractants; Coca-Cola, EDTA, HCl and NH_4OAc. The results showed that, higher mean values of the physical and chemical properties were recorded in the surface (0-20 cm) than in the subsurface (20-40 cm) soil layer and these, were significantly (P <0.05) affected by land use and soil depth. The highest mean value (19.05 mg/kg) and lowest mean value (18.46 mg/kg) of available Mn was obtained from rice farm and cassava farm, respectively. The availability of Mn in the soils under the land use systems and soil depth were considerably varied in the order of Coca-Cola > EDTA > NH_4OAc > HCl. The main concern about the study showed that, EDTA-Mn had significant negative correlation with soil pH (r = -0.732). HCl-Mn had significant positive correlation with OM (0.739**) but, significant negative correlation with pH (r = -0.842**). NH_4OAc-Mn had significant positive correlation with SOM (r = 743**) but, significant negative correlation with ECEC (r = -0.673). Coca-Cola-Mn had significant positive correlation with SOM (r = 810**) and ECEC (r = 0.827**) but, significant negative correlation with sand fraction (r = 705**) and pH (r = -0.779**). The study indicates that, notable soil properties such as texture, SOM, pH and ECEC significantly influenced the availability of manganese in soils of the study area.**

Keywords: Coastal plain sand, land use system, Mn, physico-chemical properties, soil depth, Umudike.

INTRODUCTION

Soil is vital to agricultural production, and with the rapidly increasing population on land to meet the demand for food and fiber, is becoming enormous. The changes in soil properties depends on land use as well as management practices (Sharma *et al.*, 2005). Land use and practices, can greatly influenced soil physiochemical properties which in turn, affects the availability of micronutrients (Cu,

Fe, Mn and Zn). Land use involves the management and modification of natural environment. Land uses and land management practices have a major impact on natural resources including water, soil, nutrients, and plants. Change in land use usually leads to a change in cultivation management, which can have a marked effect on the soil properties (Hassan et al., 2016). In most cases it is the major factor in determining soil fertility (Fayissa, et al., 2015**)**. It is important to gain sufficient knowledge about the effects of different types of land use on soil properties and on the capacity of the soil to fulfill certain functions. The capacity of soil to function can be reflected by measured soil physical, chemical and biological properties (Kiflu and Beyene, 2013). Soil properties deteriorate with change in land use especially from forest to arable land (Ogeh and Mbagwu, 2006; Oguike and Mbagwu, 2009). The improper cropping system may lead to erosion and leaching of soil nutrients which in turn adversely affect the physicochemical properties of the soil. Apart from NPK, the soils of the study area are becoming deficient in available micronutrients cations such as Cu, Fe, Mn and Zn. Different land use system influence availability of these cations by altering their distribution and chemical forms through the influence of soil pH, OM, texture and CEC (Dhaliwel et al., 2009). The main factors that actually determine the amounts of available micronutrients to plants are importantly related to soil conditions such as; parent material, soil reaction, soil texture, soil organic matter and CEC and in fact, plant species (Kumar and Babel, 2011; Yi et al., 2012). Accordingly, the effects of land use pattern on micronutrients accumulation in soil have been investigated elsewhere which, focus mainly on cultivated, forest and grazing land (Yeshaneh, 2015; Ivana et al., 2015).

Soil properties are very important land characteristics particularly when they are to be put into agronomic uses. Different land use types often occur on similar soils or same land use type on dissimilar soils. However the efficiency with which land use systems can be optimized will be based on the soil properties which match the land use requirements. Therefore, research on the distribution of Mn availability and variation due to land-use patterns has important theoretical and practical utilization of land. Essentially micronutrients have become a focus of public interest since analytical techniques have made it possible to detect them even in very small amounts. The purpose of this research was focused on soil factors affecting the availability of Mn in soils of agricultural land-use system in coastal plain sands.

MATERIALS AND METHODS

THE STUDY AREA

The study was conducted at Michael Okpara University of Agriculture Umudike which is located between (Latitude 05^0 29’N and Longitude 07^0 33’E). The altitude of the sample area ranges from 97 to 118 meter above sea level with slopes which ranged from level to gentle slope, respectively. The area falls within the tropical rain forest with mean annual rainfall of 2200 mm, distributed over nine to ten months in bimodal rainfall pattern; these are the early rain (April to July) and late rains (August to October) with five month dry season and short dry period in August popularly called August break. The relative humidity varies from 74% to 87% while, monthly minimum air temperature ranged from 20^0c to 24^0c and monthly maximum air temperature which ranged from 28^0 to 35^0 (NRCRI, 2016). The area is also subjected to severe water erosion during rainy seasons, causing nutrient losses. As there do not exists much possibility of increasing agricultural production in the university environment, due to increased pressure on other land use systems (construction of classroom blocks, offices, students’ hostels, recreational parks, etc).

SITE SELECTION AND SAMPLE COLLECTION

At the beginning of the study (April, 2017), a general visual field survey was carried out to have a general view of the variations in the study area. Representative soil sampling sites were selected from five land use types which were categorized into: cultivated (cassava farm), natural fallow (legume fallow), flood plain (rice farm), forested (reserved) and pasture (grazing) lands, respectively. A random soil samples from 0-20 cm and 20-40 cm depths were collected using a soil auger to make composite samples and replicated three times (different fields) for each land use type, within the study area. A total of thirty (30) soil samples (5 land use x 2 depths x 3 replicates) were collected for the study. The study sites were geo-referenced with the aid of global positioning system (GPS) and their coordinates well documented.

SAMPLE PREPARATION AND ANALYSIS

The soil samples collected were air-dried and passed through a 2 mm sieve for the analysis of selected soil physical and chemical properties and for contents of available Mn. Separate soil core samples from the 0-20 and 20-40 cm depths were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination.

Analysis of Soil Physical Properties:

Soil texture was determined using hydrometer method (Gee and Or, 2002). Soil bulk density was determined by the pycnometer method. Total porosity was estimated from the values of bulk density and particle density, with the latter assumed to have the generally used average value of 2.65 g cm^{-3} as:

$$\text{Total Porosity (\%)} = 1 - \frac{\text{Bulk density (Bd)}}{\text{Particle density (Pd)}} \times 100$$

Soil moisture content was determined by oven dry method using 10 g of fresh soil. Soil samples were kept in oven for 24 hours at 60^0C temperature.

Analysis of Soil Chemical Properties

Soil pH was determined in a 1:2:5, using the soil: water and $CaCl_2$ suspension method (Thomas, 1996). Soil organic carbon was measured using the wet oxidation colorimetric method (Nelson and Sommers, 1996). Organic carbon was converted to Organic Matter by multiplication using a factor of 1.724 (Van Bemmelen factor). Total nitrogen was determined by the Kjeldahl digestion and distillation procedure described by Bremner (1996). Available Phosphorus was determined using Bray and Kutz II solution (Olsen and Summer 1982). Exchangeable bases (Ca, Mg, K, and Na) were extracted with neutral NH4OAc. Ca and Mg was determined in the extract by EDTA titration, while K and Na were determined using the flame photometer. Exchangeable acidity was determined by leaching with KCl and the leachate titrated with 0.05N NaOH. The ECEC of the soil was determined by summing the total exchangeable bases (TEB) and the exchangeable acidity (EA) using the standard method proposed by Sumner and Miller (1996). Percentage base saturation was determined by calculating the sum of all exchangeable bases multiplied by 100% and divided by the effective cation exchange capacity as shown below.

$$\text{Base Saturation} = \frac{ExchageableCation}{ECEC} \times \frac{100}{1}$$

Determination of Available Manganese

The available Mn was determined using Coca-Cola solution, ammonium acetate (1 N NH_4OAc), ethylenediaminetetraacetic acid (0.005N EDTA) and dilute hydrochloric acid (0.1 M HCl) methods as described by Eteng et al. (2014); Eteng and Asawalam (2016). The manganese (Mn) concentration in the supernatant was determined using an atomic absorption spectrophotometer (AAS) employing atomization in an air/acetylene flame using PG-Model AA-500.

STATISTICAL ANALYSIS

The data generated on the soil properties and forms of soil Mn by different extractants were subjected to analysis of variance (ANOVA) procedure using Genstat 12th edition. Significant means were separated using fisher's least significant difference at a probability level of 5%. Pearson correlation analysis was performed to determine the relationship between soil properties and forms of soil Mn using SPSS version 20. The significance of the relationship was tested at $P<0.05$.

RESULTS AND DISCUSSION

Soil Particle Size Distribution as influenced by land use and soil depth

The contents of sand, silt and clay fractions as influenced by land use type, soil depth and the interaction effects are presented in Table 1. The highest (80.70 %) and the lowest (61.90 %) average sand fraction were observed at the surface (0-15 cm) layer of the cultivated land and the subsurface layer of the flood plain lands, respectively (Table 1). Similarly, the highest (28.90 %) and the lowest (10.40 %) average clay fraction were determined on the subsurface (20-40 cm) layer of the forested and the flood plain lands, respectively. The texture of the soils ranged from sandy loamy (SL), sandy clay loam (SCL) and Loam (L) (Table 1). The result

Table 1. Effects of land use types and soil depth on the distribution physical property of the soils area.

Land use types	Depth (cm)	Particles size			Textural class	Bulk density (mgm^{-3})	Total porosity (%)	Moisture content (gkg^{-1})
		Sand	Silt	Clay				
Cassava farm	0-20	65.8	20.6	13.6	**SL**	1.47	33.22	108.12
	20-40	68.4	16.1	15.5	**SL**	1.86	27.35	123.12
Legume Fallow	0-20	66.3	13.8	19.9	**SL**	1.22	37.84	130.25
	20-40	70.1	9.2	20.7	**SCL**	1.93	24.63	130.31
Swamp rice farm	0-20	80.7	8.9	10.4	**LS**	1.16	49.78	169.47
	20-40	77.4	6.5	16.1	**SL**	1.54	34.84	116.14
Forested land	0-20	61.9	13.3	24.8	**SCL**	1.58	38.33	146.25
	20-40	60.2	10.9	28.9	**SCL**	1.41	35.61	139.45
Grazing land	0-20	70.5	14.8	14.7	**SL**	1.97	25.43	116.05
	20-40	68.8	7.4	23.8	**SCL**	1.42	21.92	132.24
Mean		68.51	12.15	19.34	**SL**	1.57	32.90	131.14
LSD (0.05)		2.78	6.15	6.74		0.57	7.02	35.18
CV (%)		1.5	18.10	11.00		20.52	12.21	15.33
Probability		0.006	0.127	0.023		0.37	0.033	0.630

shows that the clay fraction increased whilst the sand decreased from the surface to the subsurface horizons irrespective land use systems. The high sand fractions at the surface (0-20) could be attributed to the parent material dominant in the area which is coastal plain sand since the texture of the soil is highly influenced by the parent material over time. While, higher percentage of clay content in subsoil (20-40 cm) might be due to the eluviation and illuviation process. Similar trend of gradual increase in clay content with depth was observed by Agoumé and Birang (2009) and Oguike and Mbagwu (2009).

Bulk Density, Total Porosity and Soil Moisture as influenced by land use and soil depth

With the exception of bulk density and moisture, content of total porosity was significantly ($P < 0.05$) affected by land use and soil depth (Table 1). Content of total porosity was highest (49.76%) and lowest (1.16 %) at the surface (0-20 cm) layer of the flood plain and the cultivated lands, respectively (Table 1). In general, total porosity decreased with increasing soil depth. The results obtained from this study are in agreement with the findings reported by other researchers (Oguike and Mbagwu, 2009).

Soil Chemical Properties as Influenced by Land Use and Soil Depth

The results of the chemical properties of the soils were significantly ($P < 0.05$) affected by land use, soil depth and the interaction effects (Table 2).

Soil Reaction: Changes in land use resulted in reduction of soil pH from pH-H_2O (6.40 to 4.20) and pH-KCl (5.50 to 3.70) at the surface soils (0-20 cm) and sub-surface soils (20-40 cm) layers of the natural and fallow land and the cultivated and paddy lands, respectively. Generally, the soils were found to varied widely from extremely (pH-KCl 4.51) to slightly (pH-H_2O 5.41) acid, which might probably be due to the nature of parent material of the study areas. This result is supported by those of Senjobi and Ogunkunle (2011); Yeshaneh (2015) and Hassan (2016). Basically, soil pH has a great influence on the solubility and availability of exchangeable (Ca, Mg, and K) and micronutrients (Cu, Fe, Mn and Zn) cations (Venkatesh *et al.*, 2003).

Total Nitrogen: The content of total nitrogen was highest (0.22 g/kg) and lowest (0.10 g/kg) under the surface (0-20 cm) layer of the pasture and the cultivated lands, respectively (Table 2). In general,

Table 2. Distribution of some chemical properties of the soils as influenced Land use types and soil depths.

Land use types	Soil Depth	pH (H_2O)	pH (KCl)	Basic Nutrient Elements			Org. M	ECEC	BS
				Av. P	Total N	Exch. K			
	Cm			mg/kg	g/kg	cmol/kg	g/kg	cmol/kg	%
Cassava farm	0-20	5.30	4.50	27.40	0.10	0.20	1.98	5.15	76.68
	20-40	4.20	3.90	23.20	0.07	0.18	1.46	4.95	61.73
Legume Fallow	0-20	6.40	5.50	26.20	0.18	0.38	3.29	9.36	90.59
	20-40	5.60	4.80	19.50	0.12	0.31	2.77	8.96	83.92
Swamp rice farm	0-20	4.80	4.40	19.80	0.21	0.50	5.21	13.45	73.45
	20-40	4.40	3.70	19.00	0.18	0.44	4.95	11.25	89.33
Forested land	0-20	5.80	5.00	25.50	0.20	0.43	3.70	14.48	93.37
	20-40	5.10	4.10	21.60	0.14	0.34	2.82	9.44	86.44
Grazing land	0-20	5.50	4.80	29.10	0.22	0.55	5.42	16.53	95.13
	20-40	5.30	4.00	20.30	0.19	0.53	4.54	15.34	93.22
Mean		5.41	4.51	23.26	0.16	0.39	3.61	10.82	84.39
LSD (0.05)		0.37	0.38	5.60	0.04	0.06	0.52	3.69	22.58
CV %		2.4	3.0	8.7	8.4	5.8	15.2	12.3	9.6
Probability		0.012	0.010	0.016	0.005	<0.001	<0.001	0.007	0.022

total nitrogen values decreased with increasing soil depth and these were highly significant ($P < 0.05$). The result agrees with the findings of Yeshaneh (2015) and Hassan (2016) that attributed the decrease in total nitrogen with increasing depth to declining humus with depth. The significant wide variation in total N may be due to the often uptake of N by crop plants in the cultivated land and, the fact that both forested and fallow lands have abundant litter materials which are not incorporated by plough (Wasihun et al., 2015).

Available Phosphorus: The available P content of the soils with regards to land use types and soil depth had the highest (29.40 mg/kg) and the lowest (19.50 mg/kg) values at the surface (0-20 cm) layer of the pasture and at the sub-soil (20-40 cm) layers of natural forest lands, respectively (Table 2). In general, available P contents decreased with increasing soil depth and were highly significant ($P < 0.05$). Similar results were reported by Senjobi and Ogunkunle (2011), Wasihun et al., (2015)

Soil Organic Matter: The highest (5.42 g/kg) and the lowest (1.46 g/kg) values of OM contents were recorded at the surface (0-20 cm) layer of the pasture and at the sub-soil of the cultivated lands, respectively (Table 2). This result is in par with previous studies by Yeshaneh (2015) and Hassan et al., (2016). Generally, OM decreased with increasing depth and was highly significant ($P < 0.05$). This implies that the surface soil layer is the most biologically active of the soil profile. Meanwhile, the low OM content in the upper layer (0-20 cm) might be due to the high temperature and sometimes rainfall, which accelerate rate of decomposition of organic matter Senjobi and Ogunkunle (2011).

Exchangeable K: The content of exchangeable K with regards to land use type and soil depth, was highest (0.55 cmol/kg) and lowest (0.18 cmol/kg) at the surface (0-20 cm) layer of the pasture and at the sub-surface (20-40 cm) depths of the cultivated lands, respectively (Table 2). In general, values of the exchangeable K decreased with increasing soil depth and were highly significant ($P < 0.05$).

The Effective Cation Exchange Capacity (ECEC): The content of ECEC with regards to land use type and soil depth, was highest (16.53 cmol/kg) and lowest (4.95 cmol/kg) at the surface (0-20 cm) layer of the pasture and at the sub-soil of the cultivated lands, respectively (Table 2). In general, ECEC values decreased with increasing soil depth and these were highly significant ($P < 0.05$). Similar results were reported by Mustapha et al. (2010) and Wasihun et al., (2015) and are in line with values reported by Hassan et al (2016) who reported that any soil that has < 4 cmol/kg ECEC is less

Table 3. Relationship among the distribution of physical and chemical properties under various land uses and soil depth.

Soil properties	**Physical characteristics of soil**						**Chemical characteristics of soil**						
	Sand	Silt	Clay	BD	TP	MC	pH	Org M	Total N	Av P	K	ECEC	BS
Sand	-												
Silt	0.55*	-											
Clay	**-0.88****	**-0.86****	-										
BD	-0.26^{NS}	-0.36^{NS}	0.35^{NS}	-									
TP	-0.06^{NS}	0.67*	-0.35^{NS}	-0.69*	-								
MC	-0.17^{NS}	0.19^{NS}	-0.02^{NS}	-0.47*	0.65*	-							
pH-H_2O	0.15^{NS}	0.27^{NS}	-0.25^{NS}	-0.42*	0.45*	0.37^{NS}	-						
Org M	**0.73****	0.69*	**-0.76****	-0.27^{NS}	0.20^{NS}	0.29^{NS}	0.17^{NS}	-					
TN	0.58*	0.48*	-0.61*	-0.38^{NS}	0.20^{NS}	0.39^{NS}	0.44*	**0.92****	-				
Av P	0.17^{NS}	-0.13^{NS}	-0.02^{NS}	-0.04^{NS}	0.28^{NS}	-0.41*	0.35^{NS}	-0.11^{NS}	0.08^{NS}	-			
K	0.62*	0.40*	-0.58*	-0.26^{NS}	0.12^{NS}	0.38^{NS}	0.24^{NS}	**0.97****	**0.96****	-0.05^{NS}	-		
ECEC	0.36^{NS}	-0.02^{NS}	-0.19^{NS}	-0.21^{NS}	-0.19^{NS}	0.18^{NS}	0.44*	**0.74****	**0.81****	0.22^{NS}	**0.80****	-	
BS	0.33^{NS}	0.10^{NS}	-0.24^{NS}	-0.01^{NS}	0.01^{NS}	0.36^{NS}	0.15^{NS}	**0.73****	**0.73****	-0.03^{NS}	**0.79****	**0.72****	-

BD= Bulk density, TP = Total porosity, MC = Moisture content
NS = not significant at 5% probability
*** = significant at 5% probability**
**** = significant at 1% probability**

productive. The decrease in the ECEC of this study area with depth could be due to the positive and significant correlation (r = 0.74**) between organic matter and ECEC (Table 3), as it is also evident from the fact that the higher CEC was obtained in the surface layer which also contained the highest organic matter content (Table 2). Studies by Yadav (2011); Yeshaneh (2015); Hassan et al., (2016) reported that OM is a reservoir of soil exchangeable cations and therefore increase in ECEC increases micronutrients.

Percent Base Saturation: Considering the effects of land use and soil depth evaluated, content of percent base saturation (BS) was highest (95.13 %) and the lowest (76.68 %) at the surface (0-20 cm) layer of the pasture and the cultivated lands, respectively (Table 4). In general, BS% was significant ($P < 0.05$) and decreased with increasing soil depth. Similar results were reported by Yeshaneh (2015); Hassan et al., (2016).

Correlation Matrix among the Distribution of Physical and Chemical Properties of Soils under the Land Use Types and Soil Depth

The result of correlation matrix among the distribution of physical and chemical properties of soils under various land uses and soil depth are shown in Table 3. In this study, sand fraction was positively and significantly correlated with clay fraction

Table 4. Effects of land use on the distribution of total and available Mn in soils.

Land use	Soil depth (Cm)	Available Mn ($mgkg^{-1}$)				
		Mn-EDTA	**Mn-HCl**	**Mn-NH_4OAc**	Mn-CC	Mean
Cassava farm	0-20	7.96	9.96	9.13	13.24	8.46
	20-40	5.17	4.48	8.73	9.02	
Legume Fallow	0-20	14.76	7.36	18.87	33.34	13.78
	20-40	5.96	6.67	10.87	12.43	
Swamp rice farm	0-20	36.67	17.96	15.59	25.23	19.05
	20-40	16.46	10.34	11.89	18.26	
Forested land	0-20	15.48	8.46	16.22	17.18	12.72
	20-40	12.36	6.16	13.59	12.31	
Grazing land	0-20	9.16	34.57	11.86	18.16	10.92
	20-40	6.16	14.32	7.67	15.45	
Mean		14.01	9.53	12.44	17.46	13.74
LSD (0.05)		7.43	7.52	4.76	6.79	
CV (%)		22.10	27.10	13.4	29.4	
Probability		0.014	0.024	0.028	0.033	

(0.876**), organic matter (0.728**). The silt fraction was positively and significantly correlated with clay fraction (0.883**) and organic matter (0.609*). Clay fraction correlated positively with organic matter (0.759**), total N (0.605*) and negatively correlated with exchangeable K (-0.577*). Bulk density correlated negatively with total porosity (-0.693*), moisture content (-0.465*) and soil pH (-0.417*). Total porosity was positively and significantly correlated with soil moisture content (0.650*) and pH (0.450*). Soil pH also correlated positively with total N (0.436*) and negatively correlated with ECEC (-0.439*). Soil organic matter also correlated positively with total N (0.923**), exchangeable K (0.966**), ECEC (0.638*) and base saturation (0.725**). Total N also correlated positively with exchangeable K (0.963**), ECEC (0.808**) and base saturation (0.726**). Exchangeable K also correlated positively with ECEC (0.804**) and base saturation (0.792**). ECEC also correlated positively with base saturation (0.715**). This result is in par with those reported by Yeshaneh (2015) and Hassan et al, (2016).

The Distribution of Available Manganese in Soils as Influenced by Land Use Types and Soil Depth

Significant variation of available Mn in the soil was observed among the different land use types and soil depth by different extractants (Table 4). Considering the effects of land use types and soil depth on available Mn of the soils, content of EDTA-extractable Mn was highest (36.67 $mgkg^{-1}$) under the surface (0-20 cm) layer of flood plain land and lowest (5.17 $mgkg^{-1}$) in the subsurface (20-40 cm) layer of the cultivated land with a mean of 14.01 $mgkg^{-1}$. Mn-HCl was highest (34.57 $mgkg^{-1}$) under the surface (0-20 cm) layer of pasture land and lowest (4.48 $mgkg^{-1}$) in the sub-surface (20-40 cm) layer of the cultivated land with a mean of 9.53 $mgkg^{-1}$. NH_4OAc extractable Mn was highest (18.87 $mgkg^{-1}$) under the surface (0-20 cm) layer of natural fallow land and lowest (7.67 $mgkg^{-1}$) in the subsurface (20-40 cm) layer of the pasture land with a mean of 12.44 $mgkg^{-1}$. Similarly, Coca-Cola-extractable Mn was highest (33.34 $mgkg^{-1}$) under the surface (0-20 cm) layer of natural fallow land and lowest (9.02 $mgkg^{-1}$) in the subsurface (20-40 cm) layer of the cultivated land with a mean of 17.46 $mgkg^{-1}$. The results corroborate with those reported earlier by Yeshaneh (2015), Ivana et al., (2015), Onwudike et al., (2016). The decrease in the HCl available Mn with depth could be due to the positive and significant correlation with ECEC (r = 0.598*) and negative significant correlation with pH (-0.0842**) (Table 5), as it is also evident from the fact that the higher CEC was obtained in the surface layer which also contained the highest organic

Table 5. Relationship between the distributions of available forms of Mn and some selected soil properties as influenced by land use and soil depth.

Soil properties	Extractable manganese (Mn) (mg/kg)			
	EDTA	**HCl**	**NH_4OAc**	**Coca-Cola**
Sand	-0.332 NS	-0.640*	0.253 NS	-0.705**
Silt	0.486 NS	0.098 NS	0.601*	0.304 NS
Clay	0.578*	0.415NS	0.489 NS	0.647*
Bulk density	-0.355 NS	0.232 NS	-0.505*	-0.431 NS
Total porosity	-0.676*	-0.393 NS	0.594*	0.370 NS
Moisture content	0.544*	-0.255 NS	0.032 NS	0.423 NS
pH	0.732**	-0.842**	0.603*	-0.779**
Org M	0.609*	0.739**	0.743**	0.810**
ECEC	0.271 NS	0.598*	-0.673**	0.827**

NS = not significant at 5% probability
*** = significant at 5% probability**
**** = significant at 1% probability**

carbon content (Table 2). However, the mean available Mn was significantly ($P < 0.05$) highest in Flood plain land (19.05 $mgkg^{-1}$) and lowest in cultivated land (8.46 $mgkg^{-1}$). Similarly, the highest mean value of available Mn content (17.46 mg/kg) was determined by Coca-Cola extractant while the least Mn content (9.73 mg/kg) was recorded in HCl extractant. The level of extractability was in the order of: Coca-Cola > EDTA > NH_4OAc > HCl extractant. This observation is in par with those of Kiflu and Beyene (2013), Eteng et al., (2014) and Hassan et al., (2016).

Soil factors that influenced the distribution of availability of Mn in soils under different agricultural land-use system

The data on factors responsible for the availability of Mn in soils are presented in Table 5. Results showed that significant positive correlations existed between EDTA-extractable Mn and clay fraction (0.578*), MC (0.544*), pH (0.790**), and organic matter (0.611*) but negatively correlated with total porosity (-0.676*). HCl-extractable Mn was positively and significantly correlated with organic matter (0.739**) and ECEC (0.598*) and was negatively but, significantly correlated with sand fraction (-0.640*) and pH (-0.842**). NH_4OAc-extractable Mn was positively and significantly correlated with silt fraction (0.601*), total porosity (0.594), pH (0.603) and organic matter (0.743**) and, was negatively but, significantly correlated with bulk density (-0.505*) and ECEC (-0.673**). Coca-Cola-extractable Mn was positively and significantly correlated with clay fraction (0.647*), Org. matter (0.810**) and ECEC (0.827**) and was negatively but, significantly correlated with sand fraction (-0.705**) and pH (-0.779**). The results are similar to the reports published by Ibrahim et al., (2011); Eteng et al.. (2014), Onwudike et al., (2015); Yeshaneh (2015); Hassan et al., (2016).

Relationship among the available forms of Mn that influences their availability in soil under land uses and soil depth

The result of relationship among the distribution of available forms of Mn that influenced their availability under various land uses and soil depth are shown in Table 5. EDTA-extractable Mn was positively and significantly correlated with Mn-NH_4OAc (0.734**) and Mn-Coca-Cola (0.569*) but negatively and significant with Mn-HCl (-0.631**). Similarly, HCl correlated significantly with Mn-Coca-Cola (0.790**). This result is at par with those reported by Yeshaneh, (2015) and Hassan et al.,

Table 6. Relationship among the distribution of available forms of Mn under various land uses and soil depth.

	Extactable Manganese (Mn) (mg/kg)			
	EDTA	HCl	NH_4OAc	Coca-Cola
Mn-EDTA	-			
Mn –HCl	-0.631**	-		
Mn - NH_4OAc	0.734**	-0.219 ^{NS}	-	
Mn -Coca-Cola	0.569*****	0.790 **	0.215 ^{NS}	-

NS = not significant at 5% probability
*** = significant at 5% probability**
**** = significant at 1% probability**

(2016).

DISCUSSION

Generally, decreased available in Mn from the surface (0-20 cm) to the subsurface (20-40 cm) across the land use types can be attributed to the strong association of Mn with soil texture, organic matter and pH (Table 5). The depletion of available Mn from the cultivated and the fallow lands is probably due to abundant crop harvest, organic matter degradation, and sheet and rill erosions that are aggravated by the continuous and intensive cultivation. These observations are at par with those of Kiflu and Beyene (2013), Yeshaneh (2015), Onwudike et al., (2016) and Hassan et al (2016) and with Samasundaram et al., (2009) who stated that soil organic matter increases soil micronutrients due to the chelating property of soil organic matter in holding soil micronutrients. Furthermore, high availability of Mn in flood plain land could be attributed to low soil pH as also reported by Yadav (2011) and Somasundaram et al., (2009) since soil pH is an important soil factor controlling micronutrient availability. Similarly, the correlation among the extractable Mn in the study site explained their relationships in enhancing their availability in a similar way. The observed correlations implied that they were affected by similar factors in an exchangeable way (Chhabra et al., 1996; Kumar and Babel, 2011).

The high positive correlation between OM and available Mn may be due to the formation of organic matter complexes between OC and Mn, which could be attributed to the chelating property in organic matter that helps to hold these nutrients in the soil. Similar observation were made by Hassan et al., (2016) who reported positive significant correlation between Mn and organic carbon and attributed it to the complexing agents generated by organic matter which promotes Mn availability in the soil. The significant correlation with organic matter indicates the role of soil organic matter in enhancing the availability of Mn in the soils (Kumar and Babel, 2011; Onwudike et al., 2015). Similarly, soil pH showed negative correlation with available Mn, this suggests strong acidity due to different land use types and soil depth resulting to reduction in soil available Mn. Other studies have indicated that soil pH influences micronutrients availability by favouring conditions which accelerates oxidation, precipitation, and immobilization (Ibrahim et al., 2011; Hassan et al., 2016). However, positive correlations were found between NH_4OAc- and EDTA-extractable Mn with soil pH which however provides favourable conditions for their availability. Similar results were reported by Yi et al., (2012); Ivana et al., (2015); Yeshaneh (2015). The results of the study strongly suggest that pH has direct influence on the availability of Mn in the soil. Nevertheless, increase in soil physical properties like; sand fraction, bulk density and total porosity were reported to enhance reduction in Mn availability due to its negative effects on soil microbial growth, soil aeration and water infiltration (Ivana et al., 2015; Eteng and Asawalam, 2016); Hassan et al., 2016). Accordingly, Kumar and Babel (2011) noted that other soil factors like poor aeration and microbial activity can oxidize Mn^{2+} to less available forms (Mn^{3+} or Mn^{4+}).

CONCLUSION

The study was conducted in a coastal plain sand derived soil of Umudike to investigate soil factors

influencing the distribution of available Mn from soils of agricultural land-use systems. The study demonstrated that soil physical and chemical properties were significantly ($P < 0.05$) influenced by land use and soil depth respectively. There were notable variation among the land use types and higher contents of the soil properties were found in the surface (0-20 cm) than the sub-surface (20-40) layers of soil. Similarly, the distribution of available forms of Mn by EDTA, HCl. NH_4OAc and Coca-Cola extraction methods were significantly ($P < 0.05$) different under the different land use types and soil depth. The levels of availability is in the order of Coca-Cola > EDTA > NH_4OAc > HCl. The study suggests that, notable soil properties such as texture, SOM, pH and ECEC significantly influenced the availability of manganese in soils of the study area.

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